A Technical Advisor's Manual
Managing Agricultural Irrigation Drainage Water

A guide for developing Integrated On-Farm Drainage Management Systems

Developed for the

State Water Resources Control Board

by the

Westside Resource Conservation District

in conjunction with the

Center for Irrigation Technology,

California State University, Fresno

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Dedication

This drainage management manual is dedicated to the memory of Frank Menezes, who died in 2001. Frank was an agronomist with the Natural Resources Conservation Service in Fresno, and was one of the pioneers in helping develop Integrated On-Farm Drainage Management systems to manage saline drainage problems.

Frank was a valuable asset to the San Joaquin Valley's Westside agricultural community, focusing on salinity and drainage management – in particular, development of the Integrated On-Farm Drainage Management system.

Frank's technical knowledge, practical understanding of farmers' and ranchers' needs, and warm and engaging manner made him one of the Westside's most respected and beloved individuals. Because of his tireless efforts in helping develop and implement IFDM systems on Red Rock Ranch and at other sites, this publication is dedicated to Frank Menezes.

Although many people contributed to the production of this drainage manual, three people must be recognized for their longtime commitment to the development of Integrated On-Farm Drainage Management systems.

Since 1985, Dr. Vashek Cervinka, California Department of Food and Agriculture, Clarence Finch, United States Department of Agriculture Natural Resources Conservation Service, and Morris A. "Red" Martin, United States Department of Agriculture Natural Resources Conservation Service, have been major forces in the development of agroforestry and on-farm drainage reuse to help manage salinity and shallow groundwater levels. Their early efforts and institutional knowledge of salinity and drainage on Westside soils – much of it documented in this manual – provides farmers with a viable option to ensure continued production of high quality food and fiber crops. Although all three have retired from their agencies, they continue to be involved in the development of IFDM systems while working with the Westside Resource Conservation District.

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About this manual

This manual is part of a two-part educational and outreach program to educate landowners and technical advisors about the advantages, disadvantages, costs, environmental regulations and other considerations in developing and implementing an Integrated On-Farm Drainage Management program for salinity control.

The first part of the educational program focused on the production and distribution of a guidance manual designed for landowners. It was released in 2004.

This manual is the second component of the program, and is designed to provide technical consultants and support personnel with the tools they need to assist farmers with developing and implementing an effective IFDM program.

An IFDM system can serve as a viable alternative for landowners who may not choose to participate in a voluntary land retirement program for drainage-impacted lands. Once irrigation systems have been optimized to maximize water use efficiency and to minimize the production of subsurface drainage water, an IFDM system can be designed to enable the landowner to process the resulting drainage water on-farm. Interest in IFDM is increasing.

The merits of IFDM have been recognized by the U.S. Environmental Protection Agency and the State Water Resources Control Board through the award of a Clean Water Act Section 319(h) Grant to educate farmers and to train professionals about IFDM implementation. Both manuals were funded by the grant, targeting the needs of the landowners, water/drainage district managers, engineers and technical professionals.

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Chapter 1. Introduction

A. Background

Soil salinity management in irrigated agriculture is a problem that has persisted for millennia. The "first" civilization of Sumeria is thought to have perished, in part due to the salinization of the soil in the area known as Mesopotamia between the Tigris and Euphrates River in what is present day Iraq.

The modern technique of below ground (below the crop root zone) subsurface drainage systems made of perforated clay or plastic pipe forestalls salinization, but discharge of the salty waste water from the collection system requires an outlet to an appropriate disposal area.

Disposal techniques used in the San Joaquin Valley in the past included, discharge to surface water, evaporation ponds and deep well percolation. Early use of these techniques did not take under consideration the impact to the environment.

In the mid-1980s, a significant new development cast a doubt on the efficacy of surface water and evaporation disposal systems. This development was the problem of poor egg hatches and deformed newborn offspring of various waterfowl species at Kesterson Reservoir in western Merced County. At the time, Kesterson Reservoir was the terminal evaporation facility of the federal San Luis Drain, a feature of the federal Central Valley Project that was designed to manage the subsurface drainage from the San Luis Unit lands in western Kings, Fresno and Merced counties. The original drain design was meant to be discharged into the estuary of the San Joaquin – Sacramento River Delta system, but was stopped short due to changing financial conditions and emerging environmental laws, rules and regulations.

The investigation into the cause of the environmental problems revealed that the drainage water from the western San Joaquin Valley had the potential to contain sufficient levels of the naturally-occurring element selenium (Se) to cause a mutagenic condition in birds. The environmental problems at Kesterson Reservoir lead to the closure of the San Luis Drain and subsurface drainage water disposal from the lands served by the drain was terminated in 1986.

The closure of the drain resulted in an extensive research effort by the U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, with the California Department of Water Resources and the University of California. Recently, USDA Agricultural Research Service and California State University, Fresno researchers are identifying sources of drainage water and alternatives for disposal. Much of this research is devoted to identifying the sources of drainage, the potential for reuse of saline drainage water as an irrigation supplement, the impact of saline water on plant and soil quality, and biologic systems to reduce selenium (Se) in the water. The last problem to be solved is the final disposal of concentrated saline brine and the solid salt. This problem is still being studied and several alternatives are under investigation to confirm their efficacy.

After five years of study, the USBR San Joaquin Valley Drainage Program report (1990) identified several actions that should be taken to alleviate and/or eliminate the drainage water disposal problem. The first action was source control, improving irrigation water management to reduce deep percolation losses. The second action was to use drainage water as supplemental irrigation for salt-tolerant crops. Both actions lead to a reduction of the total drainage water volume. The third action was land retirement. Drainage is eliminated because there is no longer any irrigation water being applied to the soil surface. Even with widespread land retirement there are still many acres requiring drainage service.

The Westside Resource Conservation District (WRCD) has been a sponsor and coordinator of research trying to identify environmentally friendly and economically viable methods of drainage water disposal since the early 1980s. This guide along with the Landowner's Manual is the culmination of the effort to develop a system to provide on-farm drainage water disposal in an environmentally sound manner.

Definition

Integrated on-Farm Drainage Management (IFDM) is an integrated water management system designed to manage irrigation, surface, and subsurface drainage flows within a farming unit and to provide the ultimate disposal of all drainage water including saline water in an environmentally sound manner.

This definition varies slightly from the one in the Landowner's Manual and the one found in the regulations. The above definition is very broad and includes the essence of the other definitions. It is important to understand at the outset what is involved with the IFDM concept, since this will drive the design and operation. Both surface and subsurface drainage were included in the definition because surface drainage (tailwater) will generally be low in salt and will be readily available for use on other fields without any significant changes in on-farm water management. This also implies that surface and subsurface drainage water should be separated into two flow streams, which is a requirement in many irrigation districts on the west side of the Valley.

Implicit in this definition is the consideration that source control is a significant component of an IFDM system. If a drainage water disposal system is being developed, then the goal of the integrated system should be to minimize the drainage water volume by implementing source control. Reuse of drainage water also will be a component to provide additional reduction of the drainage volume in an economic manner. The component needed for the ultimate disposal still must be completely developed. The ultimate disposal may be either on a salt-tolerant crop or in a solar evaporator.

There is no single design for a solar evaporator. Currently, various configurations of solar evaporators are being tested, and designs are being developed based on those tests. The State of California has written regulations covering the solar evaporator design, construction, operation and closure requirements, which will be presented in the Appendix along with an example solar evaporator design.

It must be emphasized at this point that there is **no standard design** for an IFDM system. The designer will be developing an irrigation and drainage water management system that disposes of saline drainage water on the farm. The manner and components of the system will be developed based on the existing equipment, crops grown and long-term goals of the farmer. For the sake of simplicity, the IFDM system described in this manual is a multi-component process implemented with reuse of subsurface drainage water. The process involves the application of "good" quality water to salt-sensitive crops and saline water to salt-tolerant crops. The number of reuse opportunities will be a part of the design and may vary from one to three reuses.

The need for data related to the on-farm water management and the regional groundwater hydrology will become apparent to the designer during project development. Water quality data for the irrigation water supply and shallow groundwater are needed for the design to meet regulatory requirements. The experience gained at pilot IFDM sites suggests that the electrical conductivity (EC) of the shallow groundwater may be a good approximation of the quality of the drainage water that will be produced by the drainage system in that field.

An IFDM system currently serves as a viable alternative for on-farm subsurface drainage water disposal system throughout the San Joaquin Valley. Evaporation ponds are being used in some locations, but the requirements for mitigation and compensation wetlands, and the environmental monitoring limit the viability of ponds to those areas with very low levels of selenium.

B. Salt Management

Salt management is a significant aspect of an IFDM system operation. It is closely linked to water management and requires the manager to develop a new set of skills and thought processes. It is important for the designer to recognize the need for salt balance in the root zone.

The salt balance, as a long-term steady state concept, was developed to prevent soil salinization and it states that the amount of salt entering the irrigated area has to be moved through the system and discharged, **salt out = salt in**. This is intended to ensure the sustainability of irrigated agriculture, and theoretically, this is true in systems that do not have large stores of native salt in the soil profile below the crop root zone. This is not the case in the San Joaquin Valley. A salt mass comparison between the input to all the fields and the output to the solar evaporator will not be an accurate representation of the salt dynamics in an IFDM system in the Valley.

In the San Joaquin Valley, the subsoil contains a large mass of salt that is mobilized by the operation of subsurface drains collecting deep percolation from irrigation. As a result, more salt leaves the system routinely than is applied in the irrigation water. Nevertheless, this does not mean that a salt balance has been achieved. Instead, it means that salt is being mined from somewhere in the soil profile.

The large salt mass in the groundwater masks any concentrating effect occurring in the deep percolate as a result of crop water use. Instead, the deep percolate is mixed with the shallow groundwater and the resulting salinity is that of the groundwater. This means that the EC of the successive reuses will reflect the groundwater quality and not the concentrated deep percolate.

Once the root zone has been leached to the salinity level needed to sustain production, it will be an integral part of the system management to control salinity levels through wise water management. It will no longer be acceptable to let subsurface drains run freely and apply excessive amounts of water to reduce soil salinity, once salinity levels in a particular field have been reduced to the desired levels. This type of operation will result in excessive accumulation of salt in the solar evaporator with no benefit to production.

The fields in an IFDM system will require periodic salinity assessment and management to correct any salt accumulation in the root zone. Leaching may need to be scheduled in the initial startup to take advantage of the disposal capability of an IFDM system. In the vernacular of the times, we will have to develop a new paradigm for salinity management. The point of measurement for a salt balance needs to be the root zone for a particular field.

There are two other terms that are used in salt management to quantify the leaching process. These are the leaching requirement (LR) and the leaching fraction (LF). Both terms often are used interchangeably, but in fact, they are not interchangeable. The LR describes the amount of water needed to maintain the salinity level in the root zone, and is often calculated using irrigation salinity and the desired soil water salinity measured in the soil. It is a theoretical calculation while the LF is a measure of the amount of water lost to deep percolation and is calculated after the fact. It is calculated using the measured EC of the irrigation water and the measured EC of the soil water.

The LR is given as $LR=EC_{iw}\ EC_{dw}$ where EC_{iw} is the electrical conductivity of the irrigation water and EC_{dw} is the desired electrical conductivity of the soil water in at the bottom of the root zone. The LF is given as $LF = EC_{iw}^{*}/EC_{dw}^{*}$ where the "*" indicates the actual values that were measured after the irrigation.

The distinction becomes important during the design phase for the irrigation and drainage system. There is a need for some deep percolation to maintain the salinity in the root zone, but there is no need for excessive amounts. As part of the design process, the designer will have to determine the amount of deep percolation needed for salinity control. As a first step, the percentage addition can be estimated using the EC of the irrigation water and a value for the soil salinity that will not result in crop losses. Then the irrigation system is selected and estimates made of the efficiency of the system. If the irrigation inefficiency is greater than the theoretical LR there is no need to add extra water to the estimated irrigation requirement. However, if the LR is greater than the irrigation inefficiency an increment will have to be added to the irrigation amount. This will be demonstrated in Chapter 3. The estimated inefficiency of the irrigation system will be the input to the design of the drainage system and will be the ultimate disposal volume, so it is critical to minimize the volume of deep percolation at this step. This also demonstrates the effect of using progressively more saline water for irrigation on the LR.

C. Regional Groundwater Flow

One of the problems facing the designer will be the influence of regional groundwater flow on the drainage system operation. Because of the fluvial nature of the soils on the west side of the Valley, there are many embedded sand stringers. These geologic features have the ability to move water throughout the region such that water captured by a drainage system may not have originated on the farm. This will make the design particularly difficult when it comes to estimating the drainage flow to be accommodated within the IFDM system.

Aerial photographs and farmer knowledge of the site, and soil surveys will help identify the problem areas and may suggest design alternatives. Deep-rooted tree species are often used to alleviate this condition by intercepting subsurface flows.

D. Source Control

Source control is simply limiting deep percolation losses from irrigation applications, supply canals and any other structure that conveys water and is possible to manage. There is very limited potential for controlling deep percolation from precipitation, but there are some water management alternatives. One management alternative that allows some available soil water storage for rainfall is using sprinklers at pre-plant irrigation and limiting the depth of application to not completely replace soil water. Adopting this practice may require a change in early season water management to ensure germination and crop stand development.

Source control is emphasized throughout this document as being the critical component in the design process and in the operation of the system.

E. Active Management

There must be active management of the entire IFDM system for it to be sustainable. This means that water management on the farm has to have a significant focus. The irrigation and drainage systems must have an integrated approach. The irrigation must be scheduled and the irrigation schedule must include the impact of the drainage system operation on crop water use from shallow groundwater. The irrigation system design has to be strictly followed. Poor implementation will result in poor distribution uniformity, excess deep percolation losses and potential yield loss.

Active drainage system management also is required. This will be further discussed in the drainage design section in Chapters 3 and 6. This will be a new concept to most managers. Drainage systems generally have been designed to operate continuously and draw the water down. There has not been consideration given to managing irrigation and drainage systems as a single entity. As the crop develops, there is a potential for significant crop water use from shallow groundwater that must be considered when making irrigation decisions. In-situ crop water use may result in less irrigation over the season and may reduce drainage water. Managing surface water to limit standing water and tailwater also will be required. If the surface water contains selenium there is the potential for impacts on wildlife that may have regulatory consequences.